AUGMENTING C-CARDS WITH MUSIC ACTIONS

Andrea Valente
Aalborg University Esbjerg
Niels Bohrs Vej 8
6700 Esbjerg, Denmark
av@cs.aaue.dk

Kirstin Lyon
Aalborg University Esbjerg
Niels Bohrs Vej 8
6700 Esbjerg, Denmark
kirstin@cs.aaue.dk

Kristoffer Jensen
Aalborg University Esbjerg
Niels Bohrs Vej 8
6700 Esbjerg, Denmark
krist@cs.aaue.dk

ABSTRACT

The paper proposes a new way of introducing ***music*** *to classes of 8 to 10 years old pupils, by adopting a recent educational tool for teaching Computer Science. Our proposal builds in fact on* ***computational cards*** *(or c-cards), a playful and intuitive mind-tool, that has been applied to a variety of Computer Science concepts.*

Here a simple extension to c-cards is presented, that enables pupils to build and play with tangible musical machine.

1. INTRODUCTION

Music and Computer Science share a dual nature: theory and practice relate in complex ways, and seem to be equally central for learners; for this no **standard** teaching approach for children has yet emerged in either of these two areas.

In fact, music is taught in most primary schools in a variety of ways, using various methodologies, to different degrees of success. The level of difficulty dependents on many factors, including age of learners, instrument being learnt, resources available, learning in group or individually, teacher's background.

In Computer Science there is a similar (if not worse) situation regarding the teaching of the subject's foundation: traditionally they are considered too theory-heavy to be taught before university. There is however a growing interest in applying Computer Science tools and methodologies to educational, and in this area a new educational tool has recently been proposed, to introduce children 8 to 10 years old to the concept of computation, seen as manipulation of symbols [2].

The tool, called **computational cards** [2] (or c-cards), is a tabletop game, where cards act as computational elements; computing machines can be defined, physically built and animated by disposing cards on a table, and moving objectified symbols on top of them, following formal rules.

C-cards have originally been designed to presents elementary school students some of the main Computer Science concepts in an intuitive, tangible and non-technical style; in this way even abstract concepts like state machines, probability and information transmission can be discussed on a concrete basis with 8 to 10 years old students.

Our proposal is then to extend c-cards, so that we can work in a constructivist and tangible way also in music education. Pupils will then be able to design and create their own musical machines, and play/learn about music and its notation in a **learning-by-doing** fashion, as advocated by Papert [9].

2. TANGIBLE INTERFACES

Tangible interfaces [15] are a powerful means of increasing the interaction possibilities, by enabling free gestures used to move and manipulate physical objects. This moves the interaction focus away from the standard WIMP interface, into something where the surrounding world is the interface [15], thereby making possible better use of the human senses and motor control.

Many musical applications involving tangible interaction have been proposed in the last few years. The music is made in function of how the tangible objects are positioned and moved. This often results in live, interactive music interfaces, where the music and the musical sounds are controlled by the tangible objects. Sometimes the individual objects include control devices, to change the state of the system or some domain-related parameters. Generally, the tangible objects positions are recognized by the computer using cameras [16], active [19] or passive magnetic devices [17], electronic [18] or other means. The audio calculated by the computer on the basis of the position and movements of the tangible objects is often augmented with visual feedback, showing, for instance, the recognized connections between the objects [20].

The approach chosen here is however more low-technological, since the actual music computation is easily made by the participants. Although a simulated environment is freely available online [14], the strength of the c-cards project [2] lies in it's simplicity: participants basically controls the data-flow in their card-circuit, thus making c-cards closer to tangible programming [11] than most of the existing tangible systems. In this work, the c-cards are furthermore augmented with an action, which defines what should happen when a peg falls on the card. This creates a link to the outside world, by controlling the action taken. Any kind of action is possible, but here we introduce the music note action. Thus, every time a peg lands on the action card, a musical note is to be played. In the lowtech version, the action is assured by one of the participants, for instance by singing the note.

3. MUSIC EDUCATION THEORIES

Several methodologies for teaching music to children have been developed in music education. Some of the well known methods include, The Orff Schulwerk, The Kodaly method, Dalcroze Eurhythmics and Suzuki.

All of these methodologies begin with children imitating sounds, learning in groups and being actively involved with music; each methodology however incorporates different aspects of music.

The Carl Orff method [3] of music teaching focuses on allowing children to create their own music. To do this he believed that feeling preceded understanding, therefore children need to participate actively to develop their skills. This included using body movement, singing, using percussion instruments etc. Initially he restricted the sounds available to two tones. As the child developed, more sounds were added. Children learnt through action, and by ear initially.

Zoltan Kodaly [13] was influenced by other music educators, so his method is a combination of other techniques. He believed that the human voice was the key to music education and emphasised the development of literacy through singing. The use of folk songs from the child's culture is also important in his methodology. The Kodaly method breaks down the learning of music into a series of concepts (or components); then applies a sequential learning process to each one. This sequential learning process follows the natural developmental pattern used in learning a language, which is, aural, written and then read. The notation reading process is divided into different levels, starting with simple pictures, and ending with standard music notation.

The Dalcroze method [4] can be divided into three branches: eurhythmics, solfege and improvisation. Eurhythmics uses kinetic exercises to develop music skills, e.g., clapping, stamping etc. Solfege incorporates the auditory, cognitive, and rhythmic skills developed through eurhythmics. It uses the voice to study pitch relationships, and links these experiences to music theory and notation. Improvisation combines the first two skills in order to create music. The three essential principles of this methodology are listening, theory follows practice and improvisation.

The Suzuki Method [10] focuses on the teaching of violin. This method also teaches sound before symbols. Students are encouraged to observe by listening, then imitate sounds. They should then compare the two. He also believed music should be taught in a similar way to that of a language, in that language is learned through imitation, and only after an extensive vocabulary should written symbols be introduced. The pupils also learned within groups, similar to that of the other methods discussed here.

In this small survey of methodologies, we also like to include the music section of the **5-14 curriculum** that is used in Scotland, for 5 to 14 year olds learners, focusing on the level most suitable for 8-10 year olds.

5-14 guidelines in Scotland [12] provide an overview of what a child should achieve by a certain age. They have 6 levels divided from 5 to 14 year olds: in our case the appropriate levels are B or C. The guidelines for music outline various strands, e.g., voice, instruments, inventing and listening. Formal notation is not taught initially.

4. C-CARDS

The **computational cards** game [2], is a tabletop game, where cards are computational elements. A **card** is a square piece of paper, and it has one **port** and one **cut** on each of its four sides, like a puzzle tile. When two cards are laid aside, ports and cuts connect in a complementary way. The behavior of a card is defined by the arrows drawn on it.

A set of c-cards, called **deck**, is represented in figure 1, and it is composed of 8 basic types of cards: source and pit (first row), cross, CCW and CW-turn, confluence (second row), then switch and random cards (third row). An empty card is also present, at the end of row 3, to be customized by the learners.

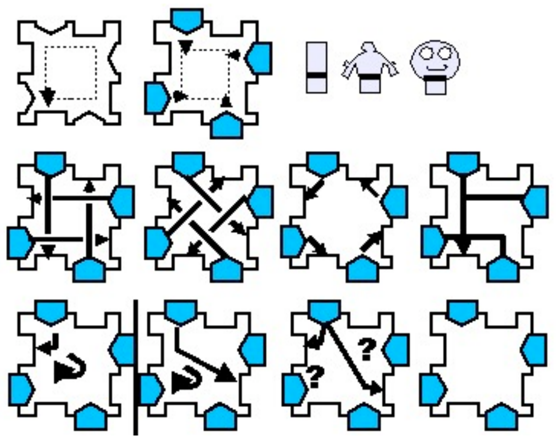

Figure 1. The deck of c-cards

To play a game at c-cards, pupils need to print some copies of the deck, then cut free the cards and some pegs (top-right in figure 1). At this point they are ready to compose a card circuit, by connecting cards together; a circuit usually has some **source cards**, starting points for pegs, and some **pit cards**. To execute a computation, a peg is placed on one of the source cards of the circuit, then moved to represent the flow of information traversing the circuit. Pegs are **objectified symbols**, and run through the cards, following the rules embedded in each card, until they reach a pit card, where they stop.

A formal semantics for c-cards is defined in [2] (see figure 2): all semantics rules work up to card rotation, and are triggered by the presence of pegs landing on ports. Switch cards have two faces, hence two semantic rules: the first peg entering a switch card from the top, exits from the left and forces the card to flip on its other face; a second incoming peg will exit from the right side and the switch will flip back to its original face. Moreover, all rules are deterministic, apart for random cards.

Many abstract concepts, like the one of deterministic state machine, probability and information transmission can be discussed on a concrete basis with c-cards. Logic thinking and problem solving skills are also stimulated when tinkering with this game, and it has been shown that c-cards have many features that encourage explorations of Computer Science concepts (in [2] and [1]).

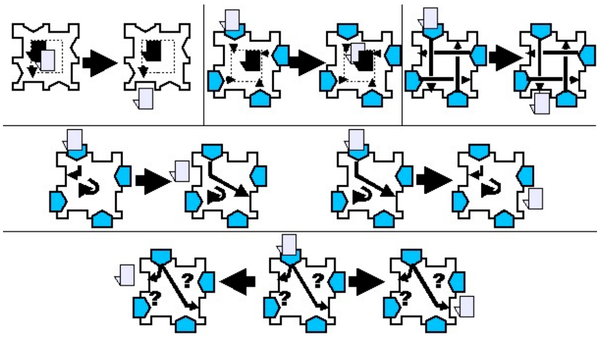

Figure 2. Semantics

C-cards are also very cheap and easy to deploy: in fact by design they have both a paper as well as web-based implementation, in the form of an editor/simulator program called E-Si [14]. Using E-Si teachers can design exercises for their courses based on traditional lectures (to visualize and animate), lab-based activities, and also for individual learning.

4.1. Extension to music

If we want to use c-cards to create music-generating machines, we need to augment them a little, and provide each card with one associated **action** (as explained in figure 3). The action is performed each time a peg lands on one of the four ports of the card; if the action is to generate a sound, then the circuit will effectively became a music machine.

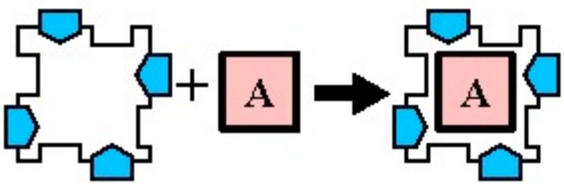

Figure 3. A card and its associated action

An example of such a circuit is depicted in figure 4; since actions are activated by pegs landing on ports, all but source cards can perform actions (in fact the source is the only card that has no ports). Moreover if silence is considered an action, we can consistently assume that every card in a circuit always has one attached action. Therefore it is possible to define, for each possible path of computation in the circuit, a unique string, representing the sequence of actions performed up to that moment: in the case of the musical circuit in figure 4, the string grows from empty to "AB", and can be interpreted as the musical pattern played by the circuit.

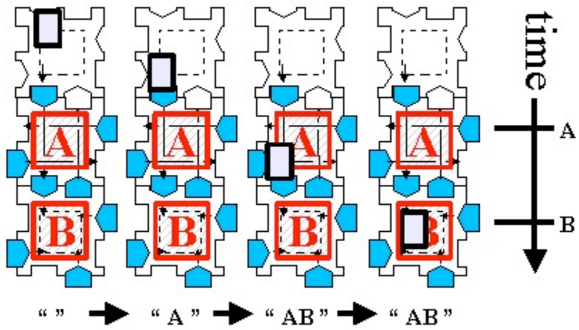

Figure 4. A simple musical machine

In c-cards, at each step, the peg crosses exactly one card, so the only thing we need to do in order to connect the speed of a circuit to the real-time, is to set a duration for the elementary step, using a metronome, i.e. a clock global to all cards, ticking each time a peg moves in the circuit (figure 4).

4.2. Musical machines

Now that we have equipped c-cards with a mechanism to play sounds, we can consider what kind of examples and exercises can be given to the pupils.

Figure 5 shows a simple circuit that plays a rhythm composed of two different sounds; this is close ideas from both the Orff method, where only 2 notes are used at first, and the Kodaly method, where stomping is introduced quite early, together with singing.

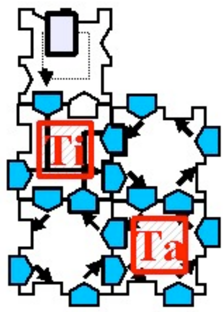

Figure 5. A rhythmic example

A more advanced music machine is depicted in figure 6. The peg will run clockwise in that machine, and play the first 5 notes of **row your boat**. Note however that we express notes as numbers only to differentiate their sound, not as a specific formal notation. As a matter of fact also in the Kodaly method any set of symbols can be used to represent sounds, while gradually working towards the standard symbols.

The actual sequence of actions performed by this circuit is:

4→ 4→ 4_5→4→Pause→Pause *(1)*

where the **4_5** action represents two half-beat notes.

A different way to express half notes could be to double the length of the circuit, so that each action will stand for a half-beat, with some extra notation for duration.

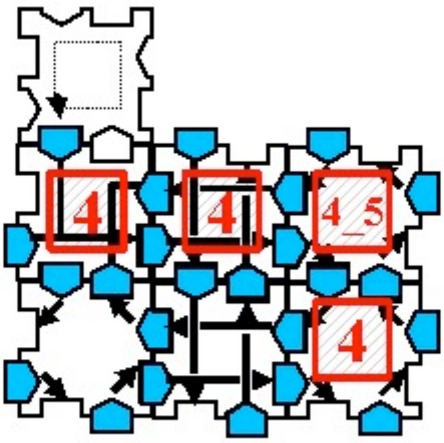

Figure 6. The beginning of "Row your boat"

The fact that our circuits can be linear as well as circular suggests that we can express simple patterns as well as canons: a second peg can be set in a circuit some time-steps later than the first, creating a canon-effect.

Thanks to the random card, it is possible to express more complex rhythmical patterns. The circuit in figure 7, for example, can generate two basic patterns

Ti→Pause→ Ta→ Pause *(2)*

and

Ti→Pause→Ta→Ta→Ta→Pause *(3)*

and all their possible interleavings, like:

Ti→Pause→Ta→Pause→ *(4)*

Ti→Pause→Ta→Ta→Ta→ Pause *(5)*

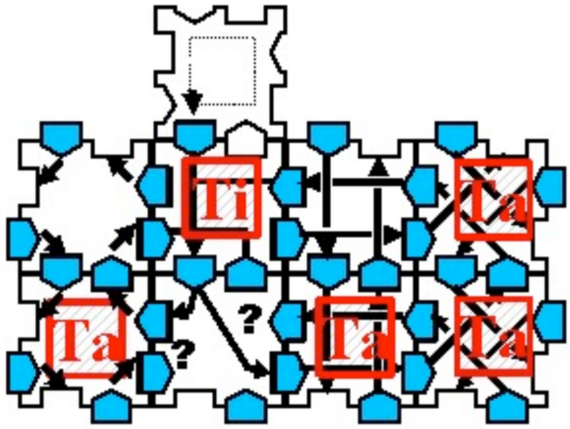

Figure 7. Conditional behaviour

Another possibility is to animate more than one circuit **at the same time**: we could start one peg per circuit and obtain something close to a polyphonic performance. Figure 8 shows the result of playing the two circuits above (figures 5 and 6) together. Since there is only one global metronome, the two circuits will always perform one step each, with a round-robin scheduling policy.

The resulting sound pattern repeats on a longer temporal scale, so we can regard parallel composition of circuits has a mean to create musical longer and more complex patterns.

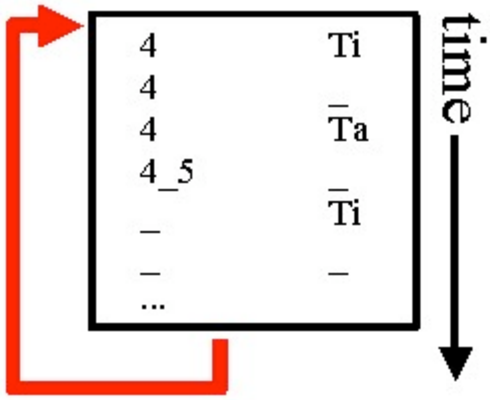

Figure 8. Two circuits playing together

The musical notation proposed above is not to be intended as a standard, stable one, but more like a suggestion, and requires more explorations from our part.

We are also aware of some limitations inherent to c-cards that will arise when applying the game to music generation, first of all of geometrical nature: it is impossible to build a loop-circuit with our card game that has only 3 cards in it. And in general rhythms with odd number of beats can be impossible to implement.

However, if we assume that each step in a circuit corresponds to one bar, then this will result in a minor inconvenience, because most of western classical music phrases comprise even number of bars.

As for a possible type of exercises, that could be presented to the learners, we suggest **top-down modelling**: a rhythm is proposed to the class, and the task is to implement it as a card-circuit.

5. MUSICAL EDUCATION

In the following we propose a possible structure for a course in music based on c-cards, by which young learners can design, perform, compose and listen at their own music devices. The course should follow the guidelines presented in [2].

At the beginning of the course some simple circuits can be shown and animated with pegs, so to explain the behaviour of all types of cards through direct manipulation; the concept of enhancing a card with an action will also be explained at this time. This strategy conforms to the **spiral** and **early bird** pedagogical patterns, and represents a bottom-up phase in the learning process, where pupils concentrate on designing and testing their own musical devices.

In the rest of the course pupils will learn how to design, duplicate, debug and enhance musical circuits. Among the main activities of the course there is **hypothesis formulation** about the nature of the observed circuits, implementation of some promising prototype and testing it.

Learners should be encouraged to study and recreate given dynamic circuits, and implement state-based musical machines (similar to the one in figure 7, above). Random cards can also play a role in exercises, to practically explain the concept of **probabilistic music generation** [6].

In a course like this, all elements employed to build the circuits are downloaded, printed and have to be cut (and folded in some cases) before use; children are physically involved in the construction of their own educational tools. This means that pupils will be able to work at home, with or without a PC, supported by their parents; then at school they could keep on exploring the music domain with tangibles (paper, cards, self-made musical instruments), reified/printed via a PC or hand-drawn.

An giant-sized out-door version of c-cards is currently under investigation, that will enable children to be pegs in a large musical circuit, composed of floor tiles, singing or playing instruments as they proceed, jumping from tile to tile.

6. CONCLUSION

In this article we present a musical extension to the c-cards game, and discuss its application as an educational tool for children.

The result is a simple and expressive tool that can be used to encourage explorations of music-related concepts, such as rhythm and polyphonic performance; moreover it is very cheap, extendible and can be easily deployed both in a classroom and at home. Using it children can design, build and perform with their own musical machines. We believe that c-cards offer a **constructive** alternative to classical musical education tools.

At a different level, this work represents an attempt at cross-fertilisation between Music (or audio in general) and Computer Science; for example, acoustic cues can help in understanding and debugging complex systems, such as large programs, and audio interfaces has been studied (see [7] and [8]).

We find the idea that musical concepts can influence the way Computer Science is taught stimulating, and this is an area we would like to investigate.

We are currently enhancing our editor-simulator to support musical cards, and working on the out-door version of musical c-cards, that presents interesting possibilities, but we cannot study it sitting in our offices. This is one of the reasons why we plan to conduct a field test in a nearby school (or possibly in the local conservatory) later this semester.

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